Real-time Observations of a Coastal Upwelling Event Using Innovative Technologies

Igor Shulman
Naval Research Laboratory
Stennis Space Center,
MS 39529
Phone: (228) 688-5646 Fax: (228) 688-7072 Email: igor.shulman@nrlssc.navy.mil

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LONG-TERM GOALS

The long-term objective is to contribute to the development of the components of limited area, open boundary, coastal nowcast/forecast systems that will resolve the time and length scales of the relevant ocean dynamics in shallow coastal environments.

OBJECTIVES

During FY 2003, PI (Igor Shulman) left University of Southern Mississippi (USM) and joined NRL at Stennis Space Center. The grant remained at USM with the objective to provide technical and programming support for Dr. Shulman's research activities conducted in the framework of ONR's "Autonomous Ocean Sampling Network II (AOSN II)" Experiment in the Monterey Bay. The support included: processing model outputs, data analysis and visualization, help in documenting results.The grant supported a USM undergraduate Computer Science student, and initial PI's collaborations with Dr. D. Nechaev (USM faculty) on adjoint data assimilation issues.

APPROACH

The approach is based on modeling experiments with the fine-resolution model of the Monterey Bay Area (named ICON model due to NOPP sponsored project "Innovative Coastal-Ocean Observing Network" (ICON)) and with a finer-resolution sub model of the ICON model (frsICON) around the upwelling front at the north of the Monterey Bay (see Shulman et al., 2003, Shulman et al., 2002a, Shulman et al., 2002b).

Research is being performed in collaboration with an interdisciplinary research team involved in the AOSN II experiment in the Monterey Bay (researchers are from MBARI, NPS, WHOI, Harvard, Princeton, Caltech, NPS, CalPoly, JPL and NRL Monterey). Research on adjoint calculations and sensitivity studies is being performed in collaboration with Dr. Nechaev (USM).

WORK COMPLETED

As it is stated in the objectives section, this grant supported a USM undergraduate student, who provided technical and programming support for completed tasks listed below:

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14. ABSTRACT
The long-term objective is to contribute to the development of the components of limited area, open boundary, coastal nowcast/forecast systems that will resolve the time and length scales of the relevant ocean dynamics in shallow coastal environments.

15. SUBJECT TERMS

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- ICON model physical fields for June –August of 2000, as well as atmospheric forcing used to force the ICON model during this time frame, were provided to the AOSN II community.
- Data and plots of the model physical fields mean values and variances (June –August of 2000) were provided to the AOSN II community.
- Movies of ICON SSTs and surface currents for Augusts of 1999, 2000, 2001 and 2002 were provided to AOSN RTOP in support of real-time operations.

Beta version of the adjoint code for the tracer routine of the ICON Monterey Bay area model was developed. Preliminary sensitivity simulations with adjoint code were conducted.

RESULTS

Table 1

PRODUCT	LOCATION	RESOLUTION	REQUEST
Physical fields for June- August of 2000	Caltech ftp site	Hourly, ICON model grid, standard vertical levels	AOSN II Executive team meeting, August of 2002
Physical fields for June-August of 2000	Caltech ftp site	Hourly, ICON model grid, 3m vertical resolution for top 100m	AOSN II Modeling and Adaptive team meetings, November of 2002
COAMPS 9km wind stress and heat fluxes for June – August of 2000	Caltech ftp site	12 hourly, 9km grid	AOSN II Modeling and Adaptive team meetings, November of 2002

Table 1 presents products from the NRL-ICON system provided to the AOSN II community in FY 2003. Physical fields for June –August of 2000, as well as atmospheric forcing used to force the ICON model, were provided. The objective of the June-August of 2000 simulations was modeling bioluminescence (BL) intensity (Shulman et al., 2003). For this reason, the focus was on accurate predictions in the upper 100m (especially velocity fields). Usually, the ICON model saves three-dimensional physical fields at daily intervals. In order to provide hourly model outputs, the ICON model was rerun for Summer of 2000, and physical fields were saved with hourly frequency. Physical fields were provided on standard vertical levels, as well as with 3m resolution in the top 100m. Listed in Table 1, data sets were used for development and testing of initial prototypes of adaptive sampling schemes with groups of gliders before the actual AOSN II (August 2003) experiment. Simulations of an autonomous glider fleet performing temperature front tracking were conducted by the Princeton group. In these simulations, the ICON model predictions were used as the forecast model data set, and the CODAR and aircraft-observed SST data were used as the “truth” data (Leonard, 2003; Fiorelli et al., 2003).

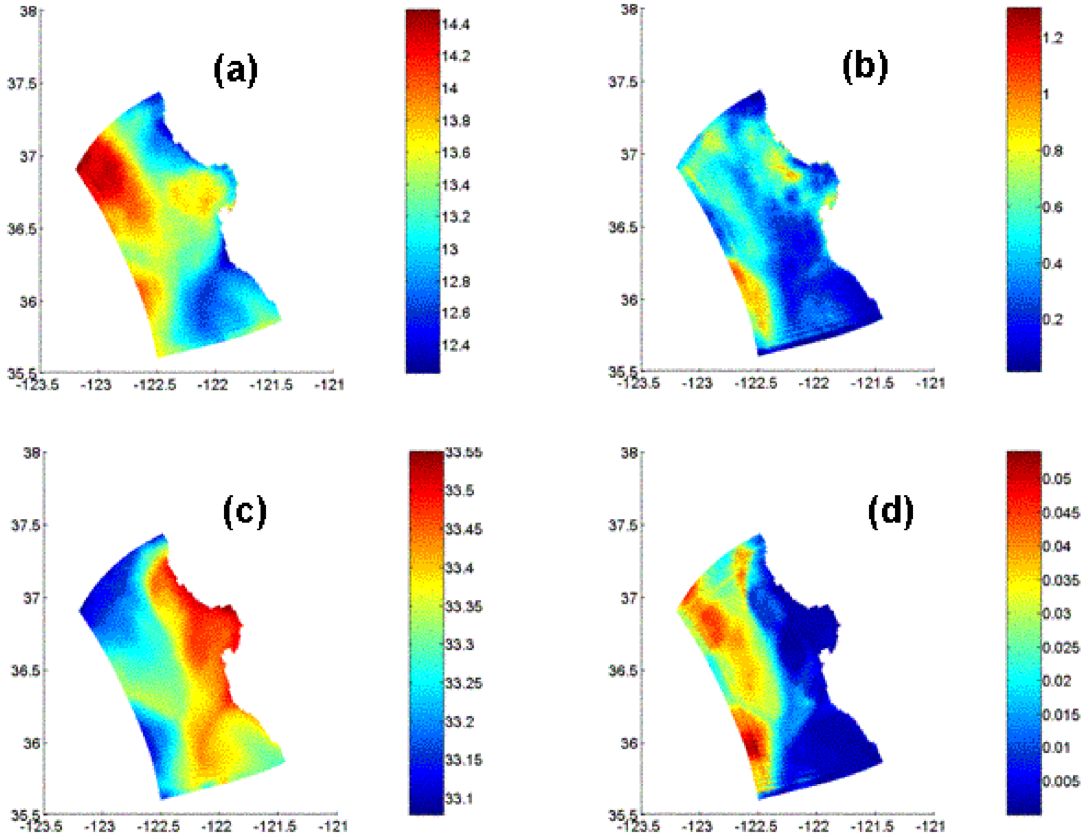

Figure 1. The ICON model mean and standard deviation of SST and surface salinity for August of 2000: (a) mean of SST; (b) standard deviation of SST; (c) mean of surface salinity; (d) standard deviation of surface salinity.[Mean fields show cold and saline upwelling filaments; warm mesoscale eddy between them, and a front between upwelled water and flowing south California Current. Standard deviation maps indicate strong variability in and around upwelling centers as well as along the western boundary of the ICON model (where there is strong interaction between California current and offshore advected upwelled water)].

Figure 1 shows mean and standard deviation of ICON model SST and surface salinity for August of 2000. Mean SST and surface salinity fields demonstrate cold and saline upwelling filaments flowing offshore. These filaments are originated at north and south of Monterey Bay. Mean fields show a front between these upwelled filaments and the warmer and less saline waters of the California Current flowing from north to south. In between upwelling centers there is a warm mesoscale eddy which often exists in observations. Also, northward flow at the southern boundary of the ICON model is present, and this flow has warmer and less saline water masses in comparison to the upwelled water. Standard deviation maps of SST indicate strong variability of SST in and around upwelling centers, as well as along the western boundary of the ICON model where there is a strong interaction between California currents and offshore advected upwelled water. For the same reason, the area of strong variability of surface salinity is also located along the western boundary of the ICON domain.

Following results in (Shulman et al., 2003), we conducted sensitivity studies of bioluminescence intensity with respect to variability of Monterey Bay circulation patterns and anomalies of the bioluminescence concentrations over 1- 3 days prior to the observational time. Analysis of these preliminary sensitivity studies for BL surveys taken during August 2000 (MUSE) experiment is under way.

IMPACT/APPLICATIONS

In situations where it is difficult to obtain extensive data sets to validate numerical models and techniques in areas of strategic importance, our development and testing of coupling and data assimilation techniques together with extensive observational programs in and around the Monterey Bay Area allow continued development of techniques for data assimilation and adaptive sampling, atmospheric forcing, and coupling between models.

TRANSITIONS

Historical ICON model outputs were provided to the AOSN II community and were used for tune ups of HOPS and ROMS systems, skill assessments, and testing optimal control and adaptive sampling schemes with groups of gliders.

RELATED PROJECTS

NRL's "Use of a Circulation Model to Enhance Predictability of Bioluminescence in the Coastal Ocean". (PI: I. Shulman) [This NRL project represents major PI's (I. Shulman) effort in bioluminescence intensity modeling as well as in modeling support of the AOSN experiments.]

NRL's "Coupled Bio-Optical and Physical Processes (CoBiOPP)" (PI: J. Kindle)
PI (I. Shulman) is actively involved in bio-physical modeling of West Coast Ecosystem in the framework of this project. Larger scale West Coast predictions and atmospheric products are used for open-boundary and surface forcing in the Monterey Bay area models (ICON and frsICON models).

Projects funded by ONR in the framework of "Autonomous Ocean Sampling Network II (AOSN II) Experiment". Coordination with a joint effort by the Harvard, MBARI, WHOI, NPS, Princeton, CalTech, JPL, NRL Monterey, CalPoly in designing and building an Adaptive Coupled Observation/Modeling Prediction System in the Monterey Bay.

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PUBLICATIONS

Fiorelli, E., Bhatta, P., Leonard, N., Shulman, I., "Adaptive Sampling Using Feedback Control of an Autonomous Underwater Glider Fleet", Proceedings of 13th International Symposium on Unmanned Untethered Submersible Technology (UUST'03), August 24-27, 2003.

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